PIDC Reference Event Database (REDB)

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1. Introduction and summary

The Reference Event Database (**REDB**; former Calibration Event Bulletin, CEB) was established at the Prototype International Data Center (PIDC) in 1996 (Bondár, 1998a) in response to recommendations by the Group of Scientific Experts (GSE). The main purpose of this database is to routinely collect data since the beginning of the GSETT-3 period in 1995 for the calibration of the International Monitoring System (IMS) network. Selected events are small to medium sized, well-located, and uniformly distributed globally. For a **REDB** event, waveform data for all auxiliary stations and NDC bulletins are requested if possible. Then the event is re-analyzed using all waveforms, and is relocated using all information including the NDCs.

The **REDB** events are useful to produce global and region-dependent corrections for IMS stations, to verify regional travel-time curves proposed on the basis of tectonic structure, to test location procedures, and to refine error estimates. They have been used at the PIDC to derive/test both model based and empirical corrections (e.g. Bondár, 1997; Bondár et al., 1998; Yang and McLaughlin, 1999a). Researchers at National Data Centers (NDCs) and many other institutions also benefit from these well-located events in their location studies.

The purpose of this report is to provide a detailed account of the events in the PIDC **REDB** (former CEB) database (Yang and McLaughlin, 1999b). Recently we have changed the database name from CEB to **REDB** in correspondence with the Working Group B recommendation (WGB, 2000). A metadata table has been included in the database to document data sources. In addition, new data, including IRIS waveforms and phase picks for some events, have been added into the database. Information on data structure and procedures of this database is described in a previous report (Bondár, 1998a). The data are stored in an Oracle relational database using the CSS 3.0 schema. Data exchanges are in GSE2.0 format. The **REDB** event information can be openly accessed through the PIDC web site, http://www.pidc.org/web-bin/all_pidc.pl?ap.

As of August 2000 there are 2407 events in the **REDB** database (Table 1, Figures 1-2). Only about 26% of the events have been re-analyzed by the analysts due to limited human resources (Figure 3). About 30% of the events have been relocated using additional arrivals (Figure 4), because, besides many oceanic events, there are a limited number of participating NDCs (Figure 5). Therefore, the quality of **REDB** events is non-uniform. Event locations have generally been improved in North, Central, and South America, Australia, Europe, and parts of Asia, in contrast to Africa and many other regions in Asia.

In this report we use **bold** for database names, *italics* for database table/view/synonym names and Helvetica for table attribute names.

2. Database Structure

The **REDB** (former CEB) database consists of the full CSS 3.0 schema. However, this database does not include tables that are not directly used in location calibration. For instance, tables related to event characterization are not included. Besides the core tables, the database also includes a set of relevant tables for handling NDC bulletins, re-analysis, and station information, respectively. There are also a few non-standard tables used for maintenance purpose. A suite of

functions and procedures have been implement in the database for data maintenance. A detailed description of the database structure is given by Bondár (1998a). Minor revisions to the data structure was done in 1999 (Yang and McLaughlin, 1999b). A metadata table, *glossary*, has been added into the database recently. Table 2 lists the up-to-date core tables/views/synonyms in the **REDB** database, including *affiliation, amplitude, arrival, assoc, event, glossary, lastid, netmag, network, origaux, origerr, origin, parrival, remark, sensor, site, sitechan, stamag, wfdisc,* and *wftag*.

All **REDB** events have associated *arrival* data. The association and residuals in the *assoc* table refers to the preferred solutions indicated in the *event* table. The arrival data include those in the PIDC REB, and those revised by the analyst during re-analysis. When it is possible to obtain NDC picks, such data are also included in the *arrival* and *assoc* tables. Events are relocated after new arrivals become available so that association between the preferred solution and the arrivals is consistent.

In 1999 we updated the deltim attribute in the *arrival* table for PIDC data before September 1997 (Yang and McLaughlin, 1999b). A new method for time error estimates was installed at the PIDC by that date so that measurement errors are inconsistent before and after (Israelsson et al., 1997). If users apply the new modeling errors to these old data in event location, stations would be down-weighted. Therefore in 1999 we updated the deltim attributes to be consistent throughout the **REDB** database, as did the **groundtruth** (Ground Truth Event Bulletin; Yang et al., 2000a) and **explosion** (Nuclear Explosion; Yang et al., 2000b) databases. However, these events in the databases were not relocated after the deltim updates. Users should also be cautioned that the GSETT-3 parametric databases in the PIDC (**REB**, **LEB**, **SEL1**, **SEL2**, **SEL3**) are not updated to reflect changes in deltim. Our calculations of deltim were done using the following formulas:

deltim = min(1.07, max(0.12, 1.07 - 1.2324*log(SNR/3))) if there is SNR value, or
deltim = 0.55 if there is no SNR value, assuming SNR=7.9.

In 1999 we also updated the Norilsk station name from NRI to NRIS for PIDC data in the **REDB** database (Yang and McLaughlin, 1999b), as done in the PIDC Operational databases. Users should be aware of the potential confusion between these two existing stations. NRI is an Academy of Sciences station located at (69.4000 N, 88.1000 E); NRIS is a station located at (69.0061 N, 87.9964 E). Although station name NRI was used in the PIDC operations before 1998, the fact is that the PIDC has always used the station NRIS. Updating the station name from NRI to NRIS for data before 1998 ensures the integrity of the information. Note that there is yet a third Norilsk station, NRIL at (69.5049 N, 88.4414 E), included in the **REDB** database.

There are *wfdisc* and *wftag* tables in the **REDB** database for waveform handling. Recently we have loaded some IRIS waveforms and phase picks for 80 and 70 events in Russia and China, respectively, provided by Multimax Inc., into the database. For PIDC data, in general the waveform information is not copied from the **REB** (Reviewed Event Bulletin) to the **REDB**. It is only done when the analysts attempted to re-analyze the **REDB** events. In that case, all the waveforms available to the PIDC system are copied from the archive system, including the waveforms used in the **REB** analysis as well as all additional auxiliary waveforms if they exist. While the *wfdisc/ wftag* records remain in the database after the re-analysis is done, we do not preserve the actual waveform data files due to limitation on disk space. In general, no waveform data are collected

from the NDCs. Users of the **REDB** database are recommended to use the **REB** database directly for waveform data, except for the IRIS waveforms.

There are multiple solutions in the *origin* table for each **REDB** event. Events are selected daily from the PIDC **REB** (authored by 'PIDC_REB') or the Preliminary REB (authored by 'PIDC_LEB'). The PIDC_LEB events include those which do not meet the **REB** criteria and those which do not fall into the PIDC **REB** days (no more than two-day **REB**s per week have been released since February 20, 2000). If human resources permit, the selected **REDB** events are also re-analyzed with extra care to ensure high location quality. Efforts are made to collect as much additional information on the **REDB** events as possible, including requesting all auxiliary waveform data and bulletin data (location and phase readings from national, regional or local networks) from the closest National Data Centers (NDCs), authored by 'XXX_NDC'. Events are re-analyzed by experienced analysts using all available waveform data (authored by 'PIDC_REV%') when analyst resources are available. Events reviewed by the analyst resource outside the PIDC, Mutlimax Inc., are authored by 'PIDC_REV_IMULT' and 'PIDC_REV_MULTI' for results with and without IRIS data, respectively. The **REDB** events are also re-located using all qualified arrivals from the PIDC and NDC arrivals (authored by PIDC_REDB'). Up-to-date, 30 NDCs have designated contact persons to work with the PIDC, and most of them have contributed bulletin data upon request (Figure 5). Some of the NDCs may not be the official national data centers in their countries, but they are the organizations with which we have established contacts to obtain regional bulletin data.

Only events recorded by the PIDC system since 1995 are included in the **REDB** (former CEB) database. This is done to ensure events in this database are directly useful for IMS calibration. At the PIDC there are another two calibration databases, the Ground Truth (GT) Event Database and the Nuclear Explosion Database, where historical events may be included (Bondár, 1998b; Yang et al., 2000a; Yang et al., 2000b). All the nuclear explosion information is included in the **explosion** database. Only events with high accuracy (location better than 25 km) are collected in the **groundtruth** database where all the events with known or estimated location accuracy reside, including events prior to 1995. Independent GT information is inserted into the **REDB** only if it is a **REDB** event and it also brings in additional arrival data. In that case, this origin in the GT database may be replaced, where better information becomes available, to ensure only the best events are included in the GT database. Such GT events are implicitly identified as 'REDB:' in the GT database. If the GT information for a **REDB** event is only inserted into the GT database for the lack of arrivals, the GT origin is flagged using a prefix 'REDB-' instead. In this case, it may not replace the existing GT origin(s) in the GT database since the information would be lost otherwise.

The **REDB** database complies with the unique ID rule for the PIDC databases in general. The IDs are obtained from the *lastid* table in the operation database. The use of allocated unique IDs is monitored carefully. Before running out of IDs, a new sequence of IDs must be allocated and inserted into the **REDB** *lastid* table.

Station information, *site* table, is implemented as a view of NEIC and NDC station tables, and the PIDC site table. The local station tables are updated as needed. The NEIC station list is obtained by ftp periodically to update the NEIC station tables. The NDC bulletins are examined for new

stations or station changes so that additional requests for station information are sent out to the NDCs when necessary.

A suite of functions/procedures were developed for **REDB** database maintenance (Bondár, 1998a). These functions/procedures are dependent on system configurations, so they need to be updated as the system changes.

3. Data sources

The **REDB** database contains events selected from the PIDC **REB** ('PIDC_REB') or preliminary **REB** ('PIDC_LEB'). NDC data ('XXX_NDC') may be present if they have been obtained. In addition, a solution from the analyst's re-analysis ('PIDC_REV%') may be available. All the **REDB** events have arrivals from the GSETT-3/IMS stations. Additional arrival data from the NDCs and analyst's re-analysis may also be available. Events are then relocated using all arrivals ('PIDC_REDB'). Table 3 shows data sources in the database.

Despite the effort towards collecting uniformly distributed calibration data worldwide, the quality of the **REDB** events is uneven. Limitations are imposed by the available human and data resources. Similar to other previous studies (e.g. Bondár, 1997), we discuss the events in more detail for regions where there are participating NDCs. Figures 6-13 show NDC locations of the **REDB** events in each region. Locations of stations associated with the REDB event locations are also shown in the figures, including the NDC stations, NEIC stations (for USA_NDC), and the GSETT-3/IMS seismic stations.

3.1 North America

The quality of the **REDB** (former CEB) events is high in North America due to active NDC participation by the USA and Canada NDCs. We have obtained NDC data for most of the events and relocated them. In particular, both the Canadian and US NDCs have provided data for some events that occurred near the border. The US NDC has also provided bulletin data requested for events in/near US territories outside North America. However, these events are not as well constrained due to poor station distribution. The total number of data requests/responses for the US NDC ranks highest among all the **REDB** correspondents (Figure 5).

Figures 6-7 show the NDC locations of **REDB** events in North America. Besides the US NDC, others such as Canadian NDC have also contributed bulletin data. Most of the events have been relocated and about 38% of the events have been re-analyzed by analysts. A significant number of events in North America are being analyzed currently by Multimax Inc. and will be included in the next revision.

3.2 Central and South America

Events in Central and South America are improved using the NDC data from Costa Rica, Ecuador, Colombia, Bolivia, Brazil, Peru, and Chile (Figures 8-9). However, the improvement of event quality for many events is limited by the geometry. About 2/3 of the events have been relocated and about 30% of the events have been re-analyzed by analysts.

3.3 Eastern Asia

The event quality in Eastern Asia is highly non-uniform. Events in the Honshu region and around Russia are well located, thank to NDC contributions of bulletin data from Japan and Russia.

Figure 10 shows NDC locations of **REDB** events in Eastern Asia. A blowup map of the Japan region is shown in Figure 11; only the Japanese NDC has contributed bulletin data to these events. About 40% of events in Eastern Asia have been relocated and about 29% of the events have been re-analyzed by analysts.

3.4 Europe, Middle East, and Asia

Events in Europe, Middle East, and Asia are mostly well located due to many NDC participants, including Norway, Finland, Switzerland, Spain, Great Britain, Romania, the Netherlands, Italy, Hungary, Germany, France, Czech Republic, Croatia, Slovenia, Russia, Israel, and Pakistan.

Figure 12 shows NDC locations of REDB events in Europe, Middle East, and Asia. More than half of the events have been relocated and about 41% of events have been re-analyzed by analysts.

3.5 Australia

Figure 13 shows the NDC locations of **REDB** events in Australia. Only the Australian NDC has contributed bulletin data to these events. About 25% of events have been relocated and about half of the events have been re-analyzed by analysts.

3.6 Africa

Currently this region remains un-calibrated (Figure 2). There is no NDC participation from the African countries. About 45% of events have been re-analyzed by analysts.

3.7 Other regions

A large number of events occur in the oceans along plate boundaries (Figure 1). While these events should be re-analyzed, they have lower priority, given limited resources. In general no relevant NDC data can be obtained for these events.

4. Event selection

To avoid over-sampling of high seismicity regions, the **REDB** events are selected from the candidates for each “bin” based on the number of defining phases, ndef (Bondár, 1998a). The Earth is divided into Flinn-Engdahl geographic regions and depth (<35 km, between 35 and 130 km, and >130 km) bins. Each bin has a self-adjusting threshold, which is 10 initially and becomes the minimum ndef after reaching 10 events in the bin. Therefore, the **REDB** events are more uniformly distributed than natural event bulletins (e.g. the **REB**).

Additional steps are undertaken after a selected **REDB** event is inserted into the database:

- All auxiliary data are requested and archived by the PIDC Operations. The auxiliary waveform data are maintained by the Operations the same as other data. Such data requests must be sent out within 7 days of the event occurrence, or the data will be lost due to the limited life span of the station disk loops. Many **REDB** events do not have additional waveforms because of delays in requesting auxiliary data.
- The **REDB** event is re-analyzed and relocated by analysts using additional waveforms if analyst resources are available.
- NDC bulletin data are requested for events within or near their national territories. The NDC bulletins are loaded into the **REDB** database with caution. Various errors are corrected and non-unique station names are re-mapped to unique station codes.
- The **REDB** events are relocated using all arrivals, including those from the NDCs and/or those from analysts' re-analysis.

The hierarchy for preferred solutions is as follows:'PIDC_REB', 'PIDC_REV%', 'PIDC_REDB', with increased preference. The preferred solutions are also candidates for the GT Database where ground truth information resides. Some may meet the GT25 or GT10 criterion and are therefore automatically loaded into the GT database (Bondár, 1998b; Yang et al., 2000a).

In order to improve event locations, Source Specific Station Corrections (SSSCs) for regional phases at IMS stations in Fennoscandia and North America have been developed and applied when producing **REB** locations at the PIDC and IDC (Yang and McLaughlin, 1999a; Yang and McLaughlin, 2000). The SSSCs are also applied when analysts reanalyze the **REDB** events ('PIDC_REV%'). However, SSSCs are not used when relocating **REDB** events ('PIDC_REDB') using all stations, including non-IMS stations, to avoid mixing calibrated and uncalibrated stations.

5. Metadata

Recently we have included a metadata table, *glossary*, into the **REDB** database to document data sources (Appendix 1). It is useful in understanding and utilizing the information contained in the database. This table has been used in other calibration related databases, e.g. GT and Explosion. The metadata structure in those databases is also more comprehensive due to the nature of the information in the databases.

6. Data access

Data in the **REDB** database can be accessed via the PIDC GT web site (http://www.pidc.org/web-bin/all_pidc.pl?ap), or directly by SQLNet (Yang et al., 2000c).

6.1 Web access

At the PIDC **REDB** web site events can be selected by calendar month or day. Information provided includes not only event lists but also magnitudes and arrivals for each event, if available.

6.2 Direct database access

The **REDB** database can be directly accessed using SQLNet by users who have Oracle access at their local sites or from CMR accounts. The SQLNet connection is: sqlplus center@alfheim. Note that the password is only available for IDC and NDC personnel as well as users associated with the Defense Threat Reduction Agency (DTRA) and related research programs.

7. Acknowledgments

The success of the **REDB** (former CEB) database is largely due to NDC participation. In addition to previous acknowledged PIDC analysts and NDCs (Bondár, 1998a), we are grateful to the NDC contact people including Matthew Sibol in US, Harumi Okamura in Japan, Tariq Mahmood in Pakistan, Gonzalo Perez in Chile, Julian Silva, Harold Velandia, Luisa Fernanda Salgado, and Anibal Ojeda in Colombia, Floribeth Vega Solano in Costa Rica, Monica Segovia in Ecuador, Spiro Spiliopoulos in Australia, Rodolfo Console and colleagues in Italy, Mihaela Popa and Mihaela Rizescu in Romania, Estela Minaya and Rodolfo Ayala in Bolivia, Leo Ocola in Peru, Vladimir Gaiduk in Russia, and many others for their commitment to help.

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Table 1: REDB (former CEB) events as of August 2000.

Year	Number of events
1995	502
1996	764
1997	541
1998	248
1999	217
2000	135
total	2407

Table 2: Database tables in the REDB (former CEB) database.

Name	Type	Description
affiliation	view	Network station affiliations
amplitude	table	Arrival- and origin-based amplitude measurements
arrival	table	Summary information on a seismic arrival
assoc	table	Data associating arrivals with origins
event	table	Event to origin connection
glossary	table	Abbreviation description including data source
lastid	table	Sequential values for IDs
netmag	table	Network magnitude
network	view	Network description and identification
origaux	table	Additional information on origin
origerr	table	Errors in origin estimations
origin	table	Summary of hypocentral parameters
parrival	table	Predicted arrivals and associations for origin-based amplitude measurements
sensor	synonym	Calibration information for channels
site	view	Station location information
sitechan	synonym	Station-channel information used in wfdisc table
stamag	table	Station magnitude

Table 2: Database tables in the REDB (former CEB) database.

Name	Type	Description
remark	table	Comments
wfdisc	table	Waveform header file and descriptive information
wftag	table	Waveform mapping file with origin

.

Table 3: Data sources in the REDB (former CEB) database (*glossary* table)

Data source	Comments	Number of events
AUS_NDC	Data provided by the Australia NDC upon request	12
BOL_NDC	Data provided by the Bolivia NDC upon request	42
BRA_NDC	Data provided by the Brazil NDC upon request	2
CAN_NDC	Data provided by the Canada NDC upon request	29
CHE_NDC	Data provided by the Switzerland NDC upon request	20
CHL_NDC	Data provided by the Chile NDC upon request	70
COL_NDC	Data provided by the Colombia NDC upon request	28
CRI_NDC	Data provided by the Costa Rica NDC upon request	52
CZE_NDC	Data provided by the Czech Republic NDC upon request	2
DEU_NDC	Data provided by the Germany NDC upon request	4
ECU_NDC	Data provided by the Ecuador NDC upon request	32
ESP_NDC	Data provided by the Spain NDC upon request	19
FIN_NDC	Data provided by the Finland NDC upon request	5
FRA_NDC	Data provided by the France NDC upon request	21
GBR_NDC	Data provided by the Great Britain NDC upon request	7
HRV_NDC	Data provided by the Croatia NDC upon request	11
HUN_NDC	Data provided by the Hungary NDC upon request	18
ISR_NDC	Data provided by the Israel NDC upon request	34
ITA_NDC	Data provided by the Italy NDC upon request	49
JOR_NDC	Data provided by the Jordan NDC upon request	1
JPN_NDC	Data provided by the Japan NDC upon request	96
NLD_NDC	Data provided by the Netherlands NDC upon request	9
NOR_NDC	Data provided by the Norway NDC upon request	7

Table 3: Data sources in the REDB (former CEB) database (*glossary* table)

Data source	Comments	Number of events
PAK_NDC	Data provided by the Pakistan NDC upon request	80
PER_NDC	Data provided by the Peru NDC upon request	43
PIDC_LEB	Data from the preliminary Reviewed Event Bulletin (REB). Events without sufficient numbers of primary IMS stations may not be migrated into the REB.	25
PIDC_REB	Data from the Reviewed Event Bulletin (REB)	2379
PIDC_REDB	Data from the final results of the Reference Event Database (REDB; former Calibration Event Bulletin , CEB) using all available arrivals from analysts' re-analyses and from the NDCs.	681
PIDC_REV	Data from analysts' re-analyses of the REDB (former CEB) events using all available waveforms	478
PIDC_REV_IMULTI	Data from analysts' re-analyses of the REDB (former CEB) events using all available waveforms. Work was done by Mutlimax Inc. and IRIS data were also included.	148
PIDC_REV_MULTI	Data from analysts' re-analyses of the REDB (former CEB) events using all available waveforms. Work was done by Mutlimax Inc. and no IRIS data were included.	149
ROM_NDC	Data provided by the Romania NDC upon request	27
RUS_NDC	Data provided by the Russia NDC upon request	69
SVN_NDC	Data provided by the Slovenia NDC upon request	22
USA_NDC	Data provided by the United States NDC upon request	185

Appendix 1: The *glossary* table

In this Appendix the schema for the *glossary* table is provided. This table is not in the current schema given in the IDC Documentation, but will be included in the next revision of the schema.

Table format, table attributes, and SQL script for creating the table are described. For the attributes identical to those in the schema in the IDC Documentation, descriptions are not duplicated here but they are simply noted as "Already defined in the schema". Attributes are described in details if they are somewhat different from those already in the schema in the IDC Documentation.

1.1 *glossary* table

This table is used for storing information on metadata, such as references on data sources as well as various abbreviations used in the database, e.g. explosion type in the **explosion** database. This table is used in the databases whose information comes from diverse data sources, including the **explosion**, **groundtruth** (Yang et al., 2000a), **REDB** (Reference Event Database), and **hydroacoustic** (Yang et al., 2000d) databases.

1. Table format:

Relation:	*glossary*				
Description:	**Information on abbreviations**				
attribute name	**field no.**	**storage type**	**external format**	**character position**	**attribute description**
abbrev	1	c16	a16	1-16	abbreviation name
abbrevtype	2	c16	a16	18-33	abbreviation type
lineno	3	i4	i8	35-42	description line number
descrip	4	c80	a80	44-123	description
dir	5	c64	a64	125-188	directory
dfile	6	c32	a32	190-221	data file
lddate	7	date	a17	223-239	load date

2. Table attributes:

Name	abbrev
Relations:	*glossary*
Description:	Abbreviation name. This information is in the *origin, explo,* or *remark* tables
ORACLE:	VARCHAR2(16)
NA Value:	NOT ALLOWED
Range:	Any string up to 16 characters
Name:	abbrevtype
Relations:	*glossary*
Description:	Abbreviation type. Unique abbreviation identifier: GT category, data source, explosion type, test site.
ORACLE:	VARCHAR2(16)

NA Value:	-
Range:	Any string up to 16 characters
Name:	lineno
Relations:	*glossary*
Description:	Line number.
	Already defined in schema
Name:	descrip
Relations:	*glossary*
Description:	Description of the abbreviation.
ORACLE:	VARCHAR2(80)
NA Value:	-
Range:	Any string up to 80 characters
Name:	dir
Relations:	*glossary*
Description:	Directory of a path name for metadata
	Already defined in schema
Name:	dfile
Relations:	*glossary*
Description:	Data file name of metadata.
	Already defined in schema
Name:	lddate
Relations:	all
Description:	Load date.
	Already defined in schema

3. SQL script for creating the table: glossary30_cre.sql

```
rem FILE
rem  glossary30_cre.sql
rem
rem DESCRIPTION
rem  This creates the glossary relation for the 3.0+ database
rem definition.
rem
rem SccsID:  @(#)glossary30_cre.sql 05/2000
rem
accept tname prompt "Enter the tablename to have the structure of glossary: "
create table &tname (
 ABBREV                    VARCHAR2(16) NOT NULL,
```

```
 ABBREVTYPE          VARCHAR2(16),
 LINENO              NUMBER(8) NOT NULL,
 DESCRIP             VARCHAR2(80),
 DIR                 VARCHAR2(64),
 DFILE               VARCHAR2(32),
 LDDATE              DATE
);
```

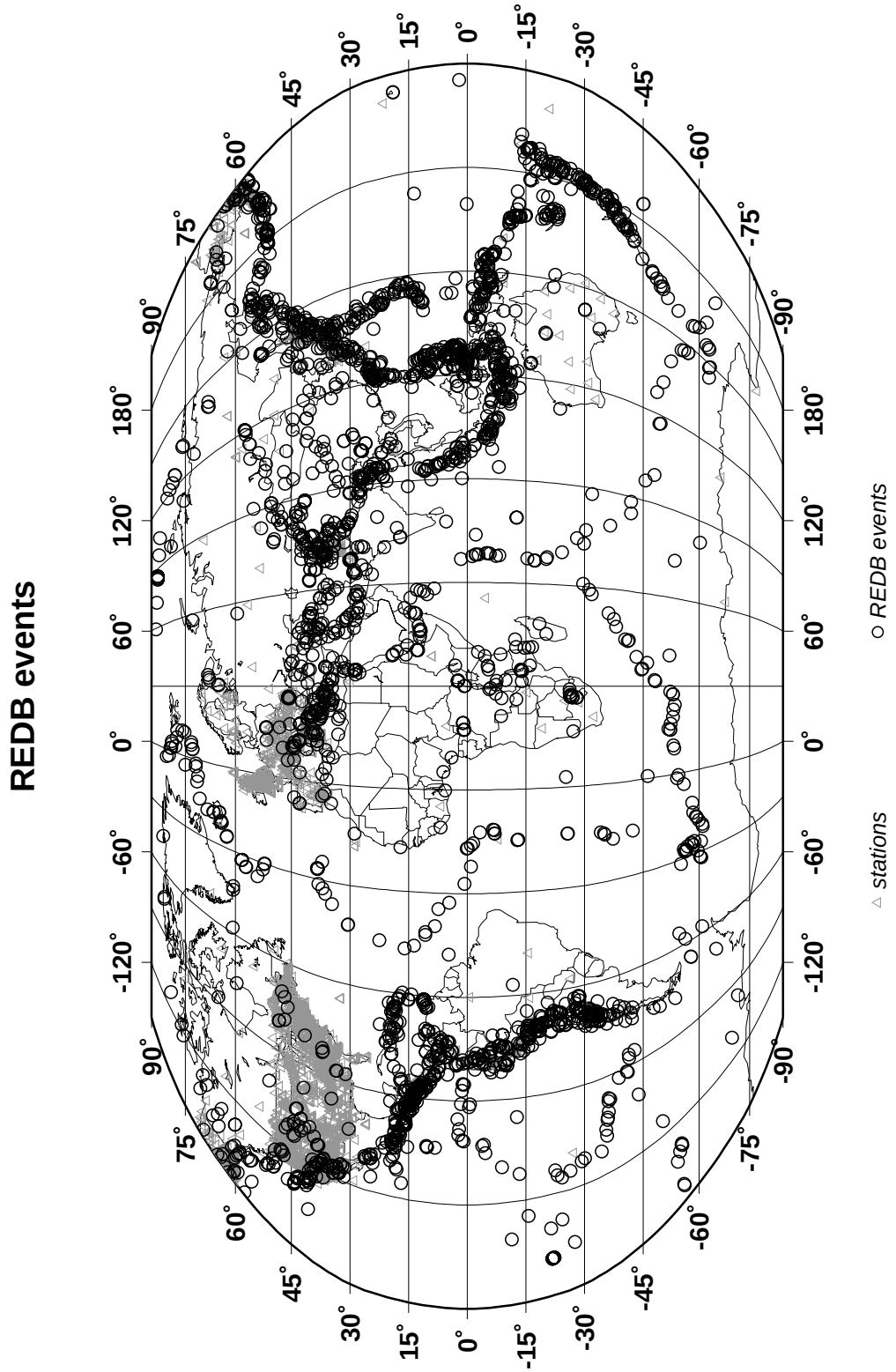

Figure 1. Distributions of **REDB** events and associated stations as of August 2000.

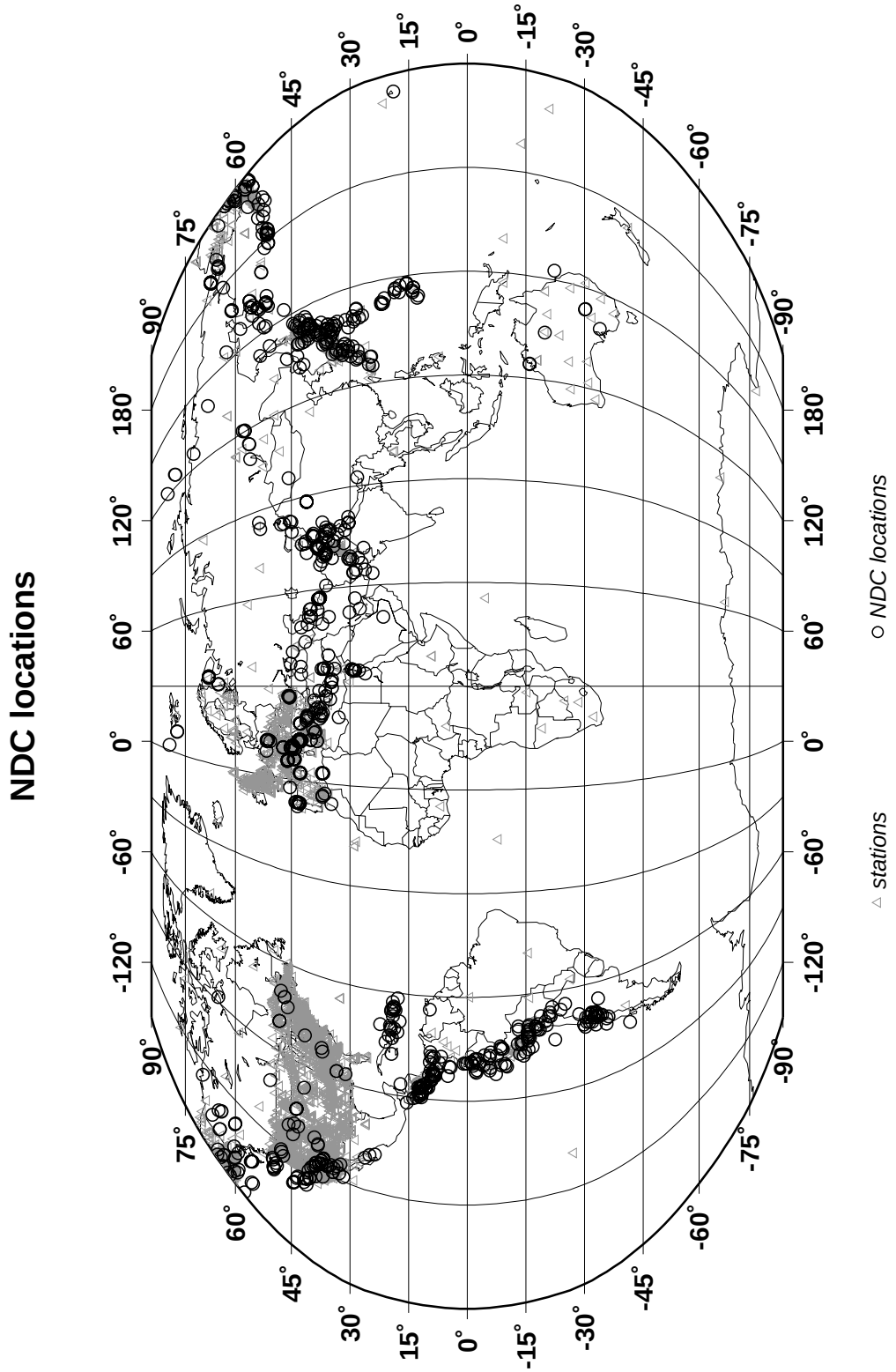

Figure 2. NDC locations of **REDB** event and station distributions as of August 2000.

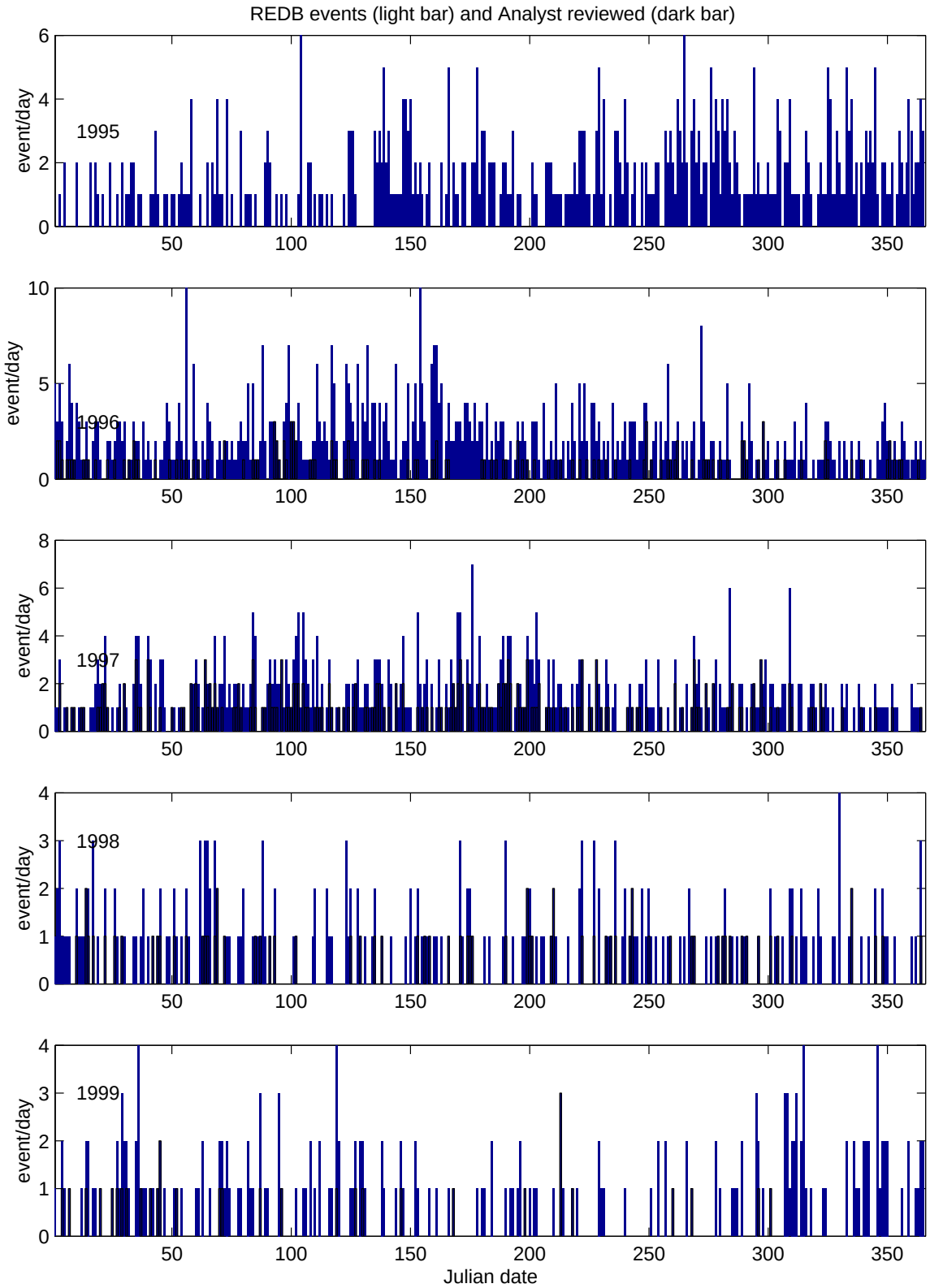

Figure 3. **REDB** events that have been re-analyzed by analysts (additional waveform data might be used if available).

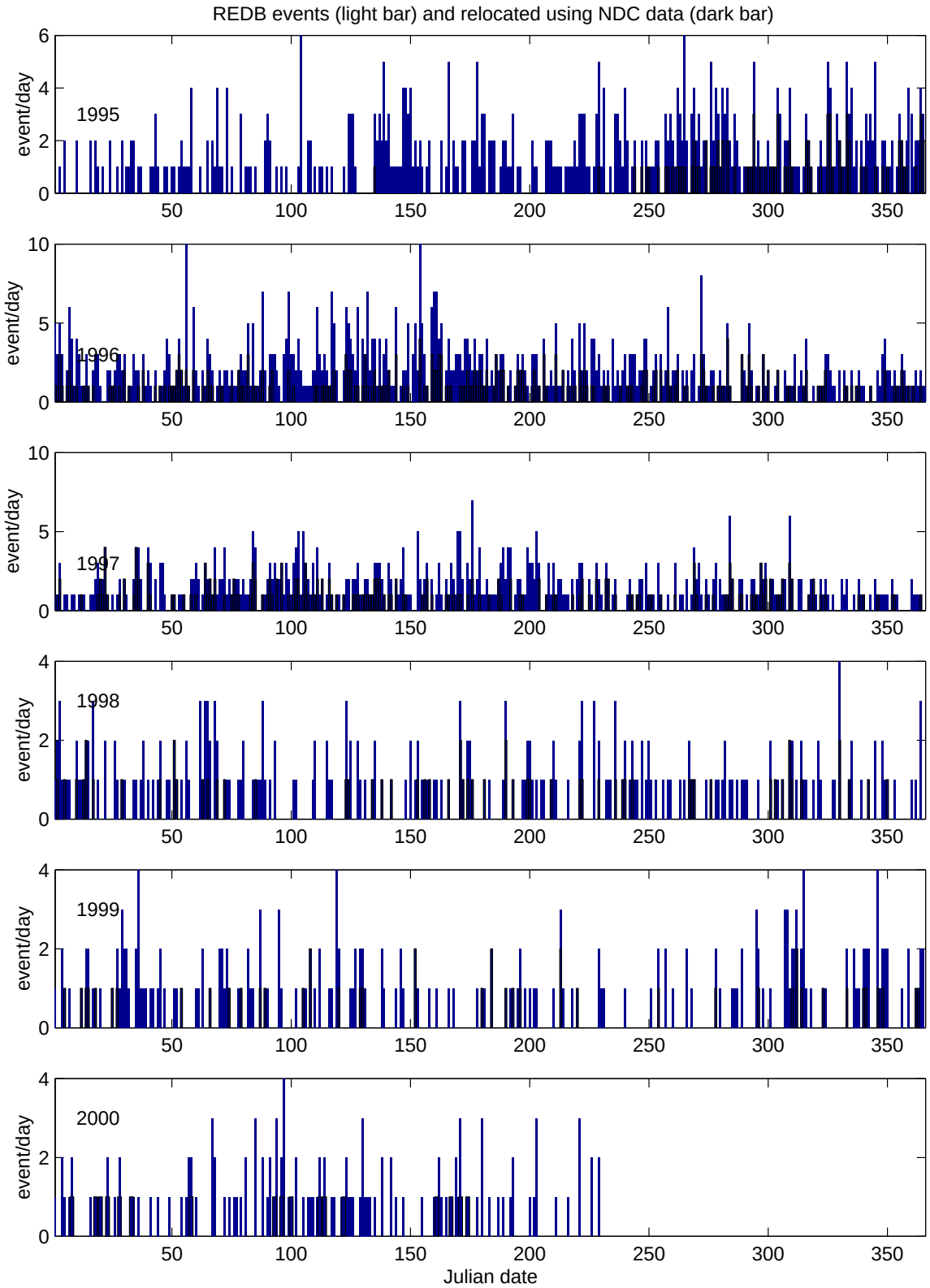

Figure 4. **REDB** events that have been relocated using additional NDC arrival data.

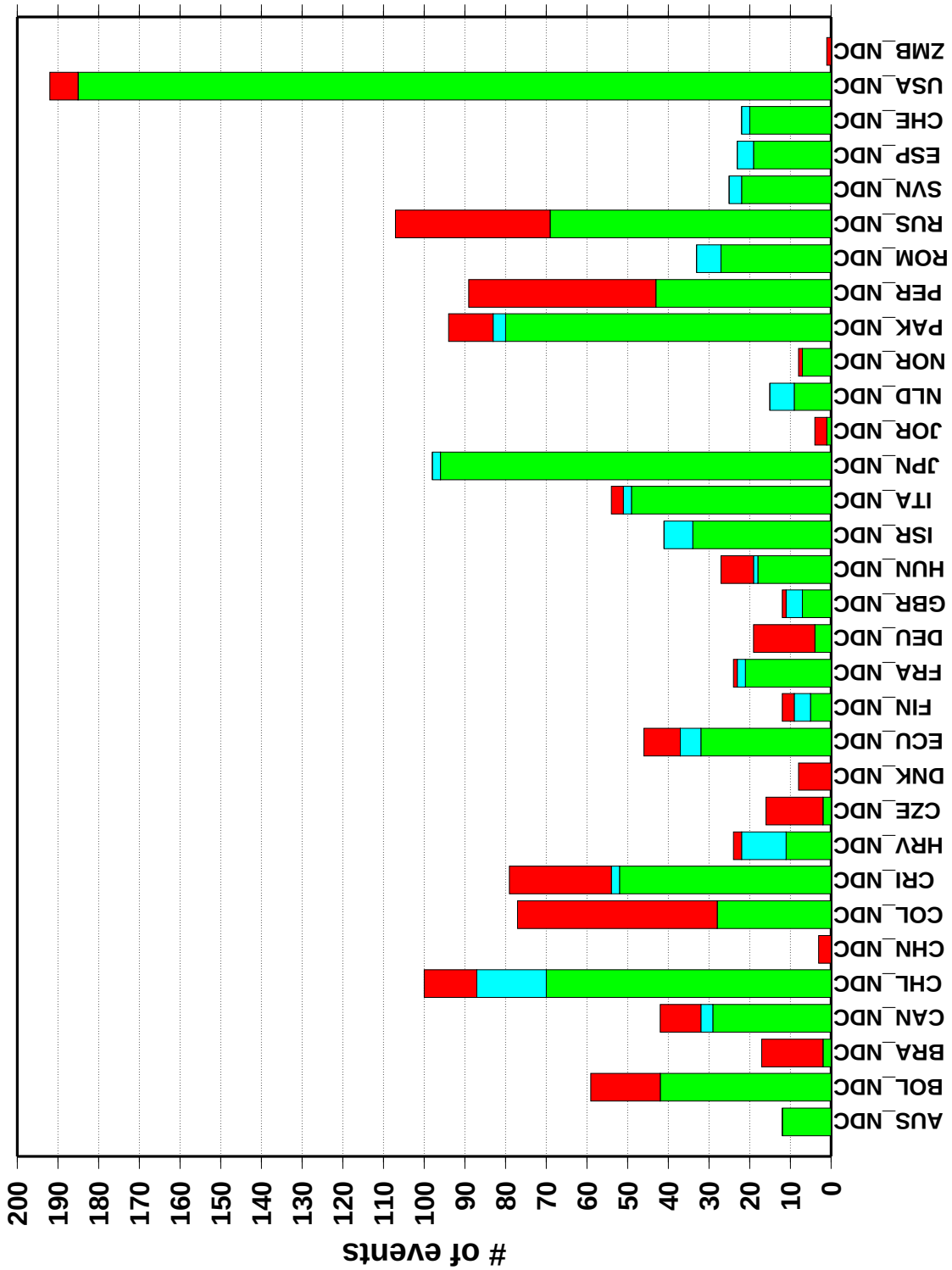

Figure 5. Number of **REDB** events requested from participating NDCs. Number of events returned with NDC data is shown in green; not recorded shown in blue, and not responded by the NDCs shown in red.

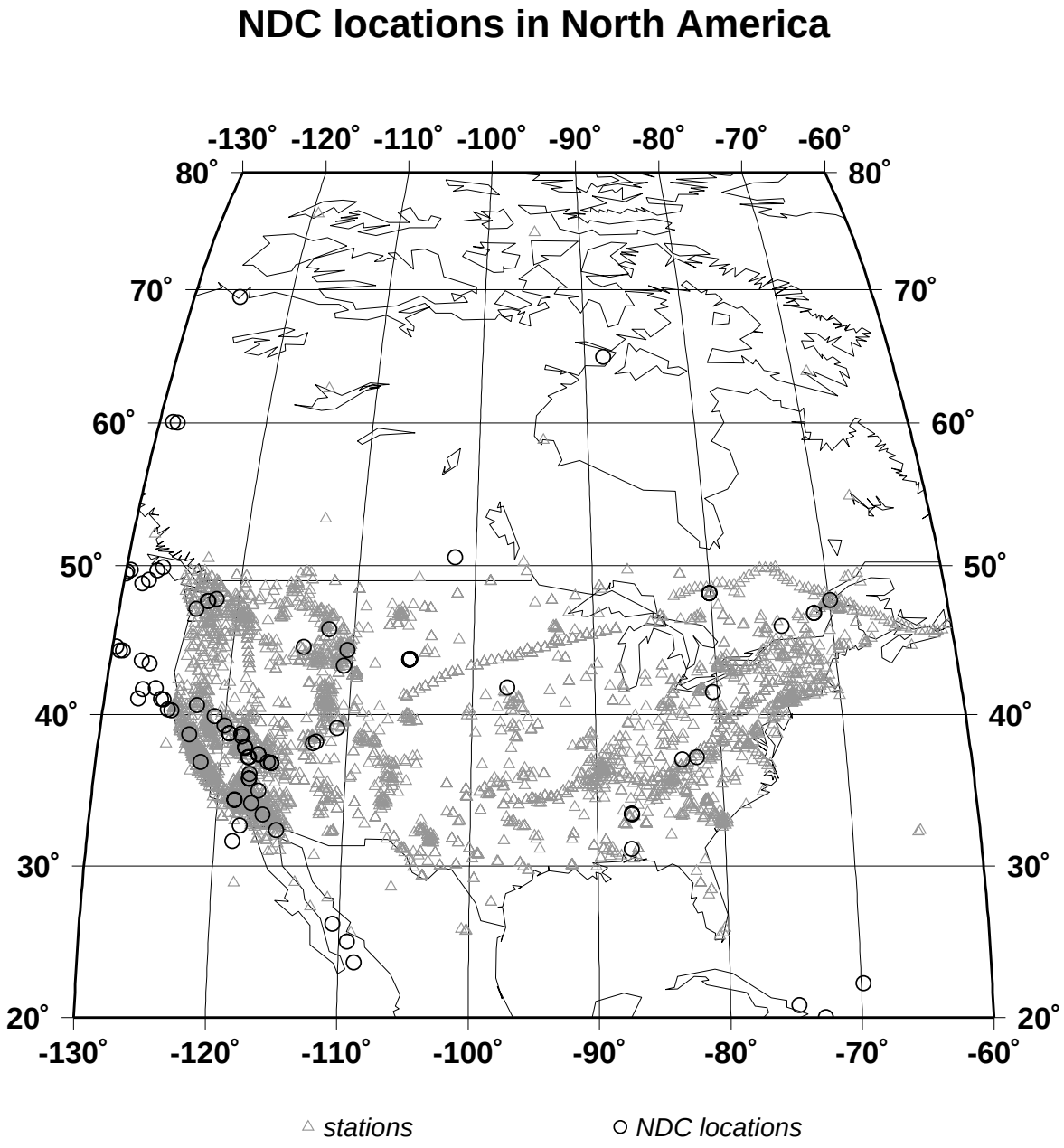

Figure 6. NDC locations of **REDB** events in North America. Both the US and the Canada NDCs have contributed bulletin data. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations, NEIC stations (for USA_NDC), and the GSETT-3/IMS seismic stations.

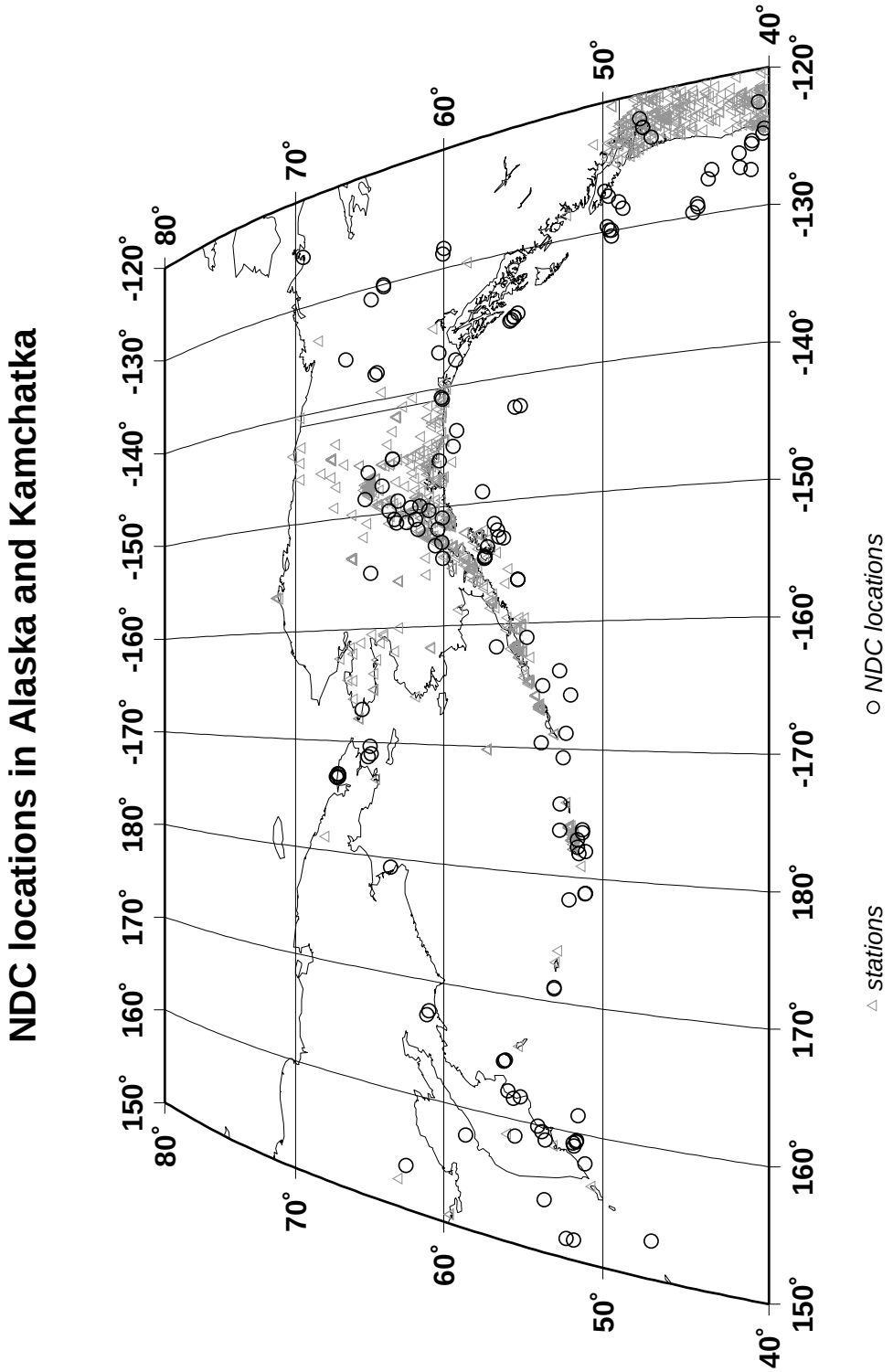

Figure 7. NDC locations of **REDB** events in Alaska and Kamchatka. Both the US and other NDCs (e.g. Canada) have contributed bulletin data. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations, NEIC stations (for USA_NDC), and the GSETT-3/IMS seismic stations.

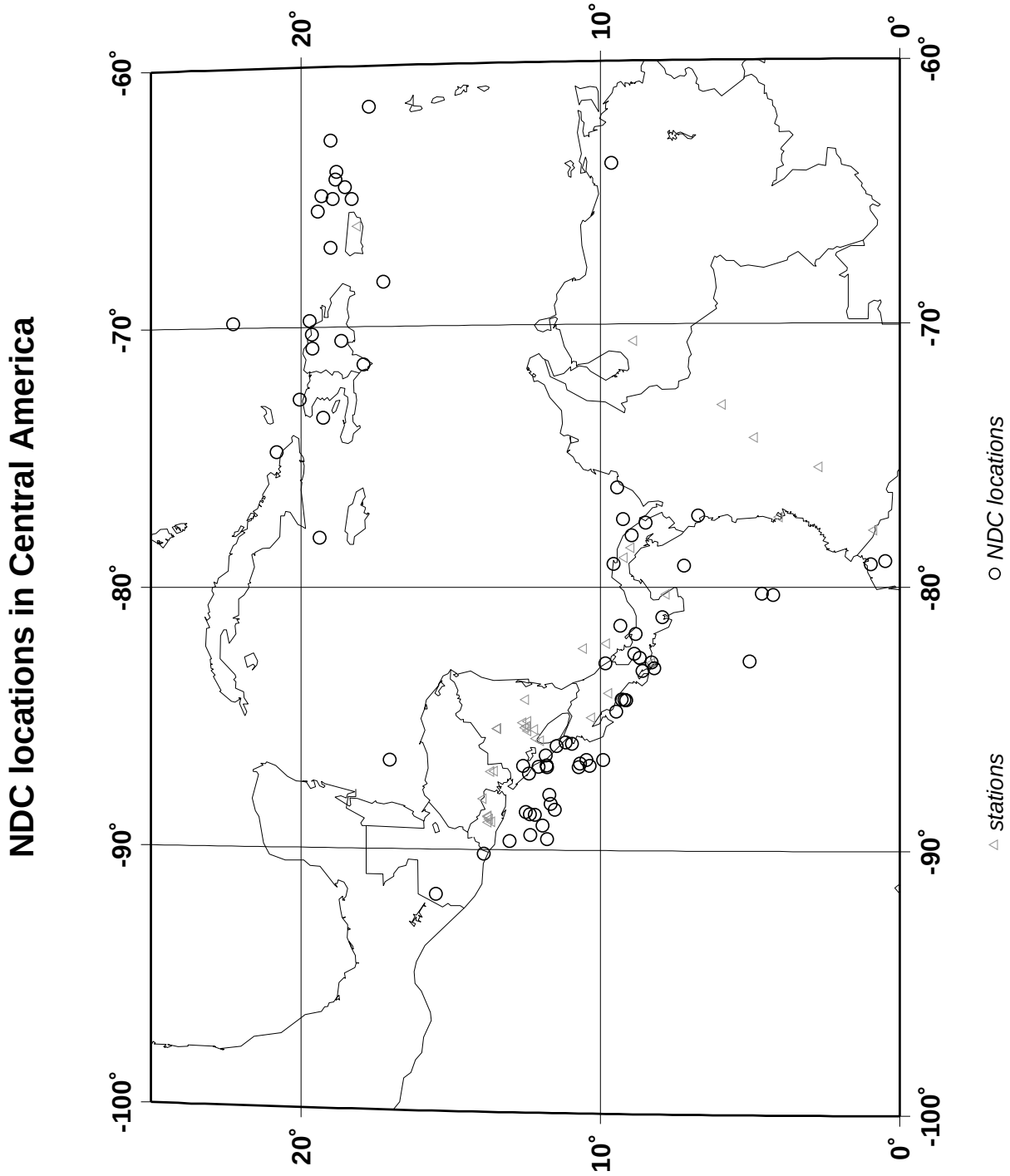

Figure 8. NDC locations for **REDB** events in Central America. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/ IMS seismic stations.

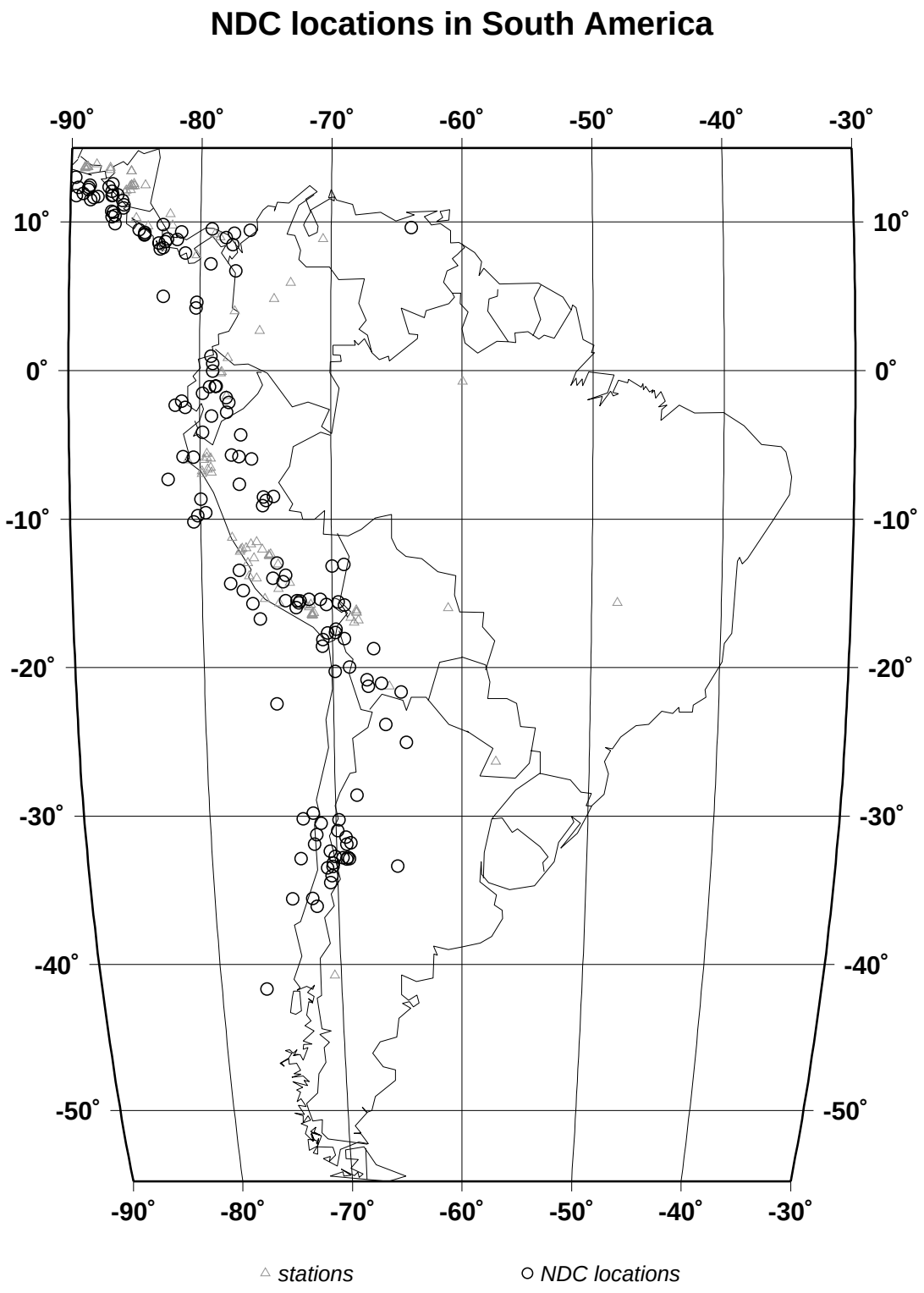

Figure 9. NDC locations for **REDB** events in South America. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/ IMS seismic stations.

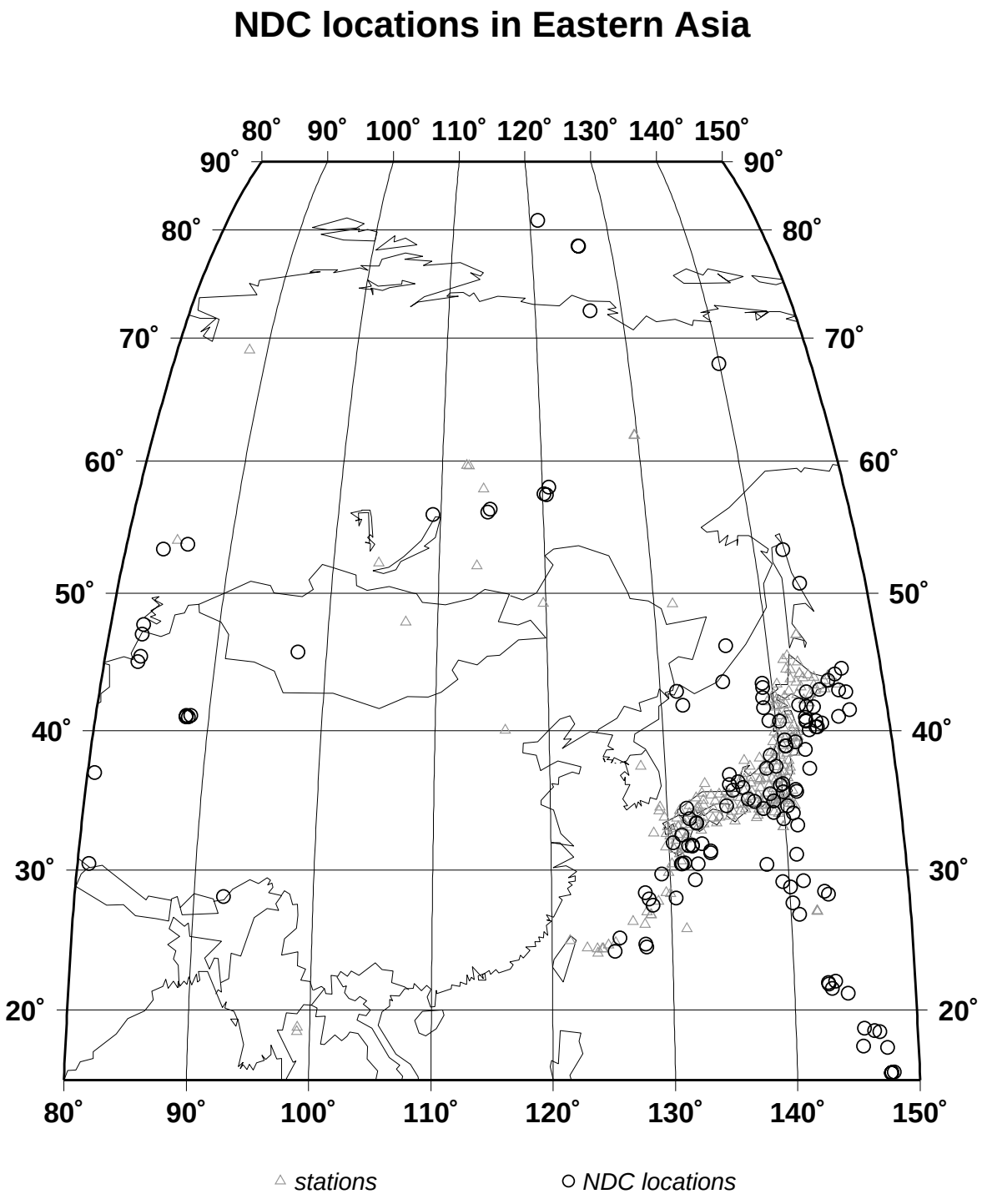

Figure 10. NDC locations for **REDB** events in Eastern Asia. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/IMS seismic stations.

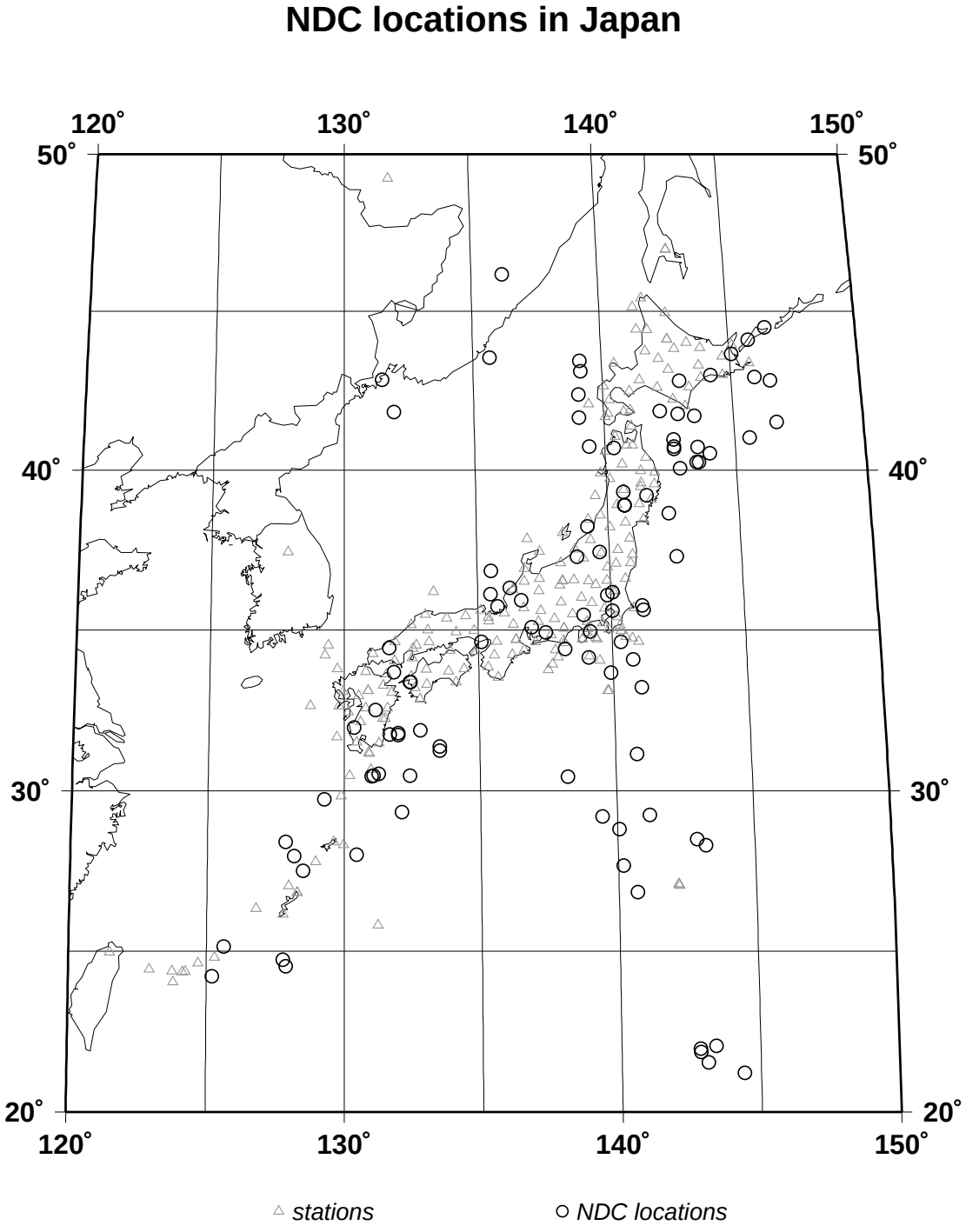

Figure 11. NDC locations for **REDB** events in/near Japan. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/IMS seismic stations.

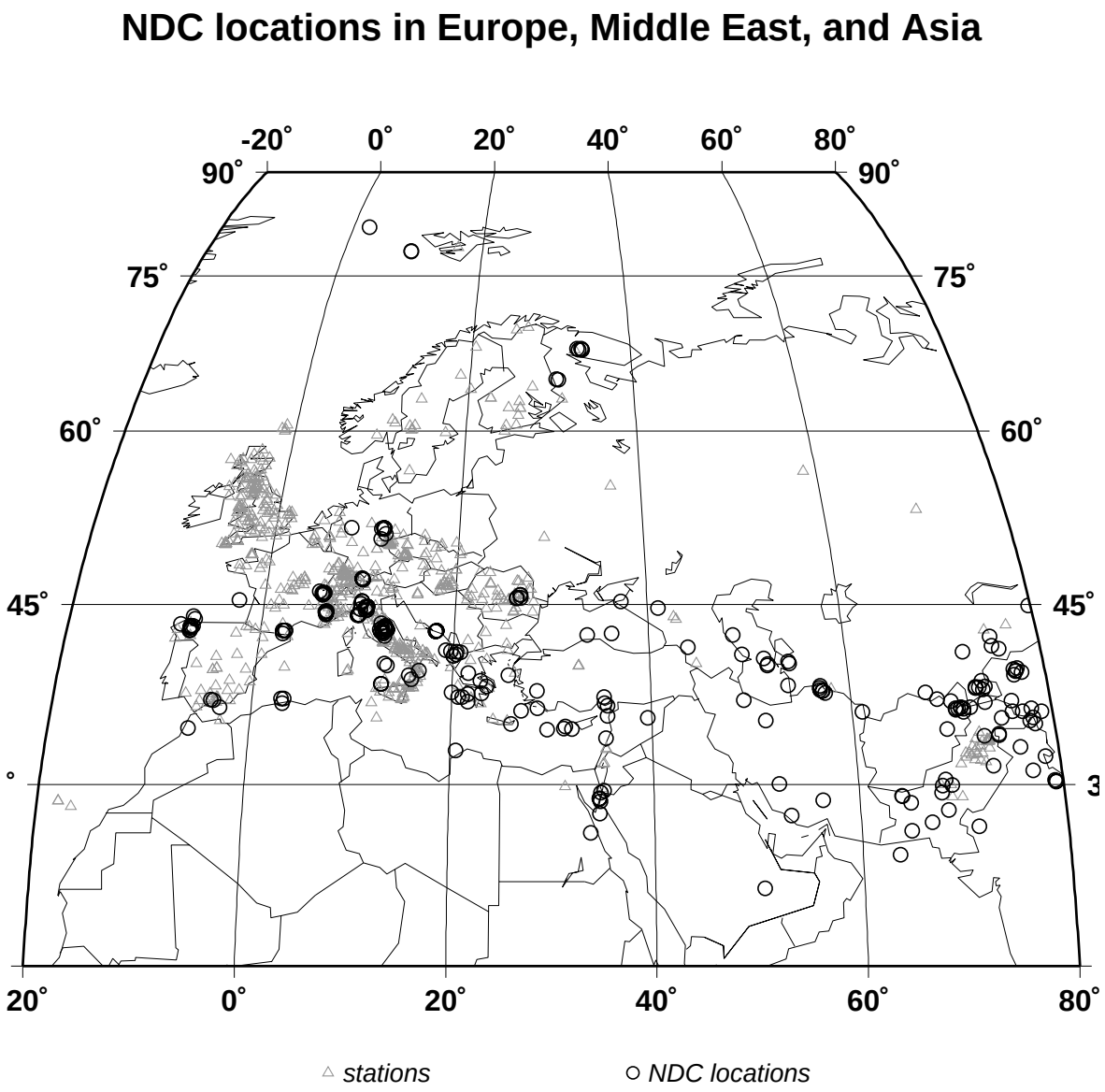

Figure 12. NDC locations for **REDB** events in Europe, Middle East, and Asia. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/IMS seismic stations.

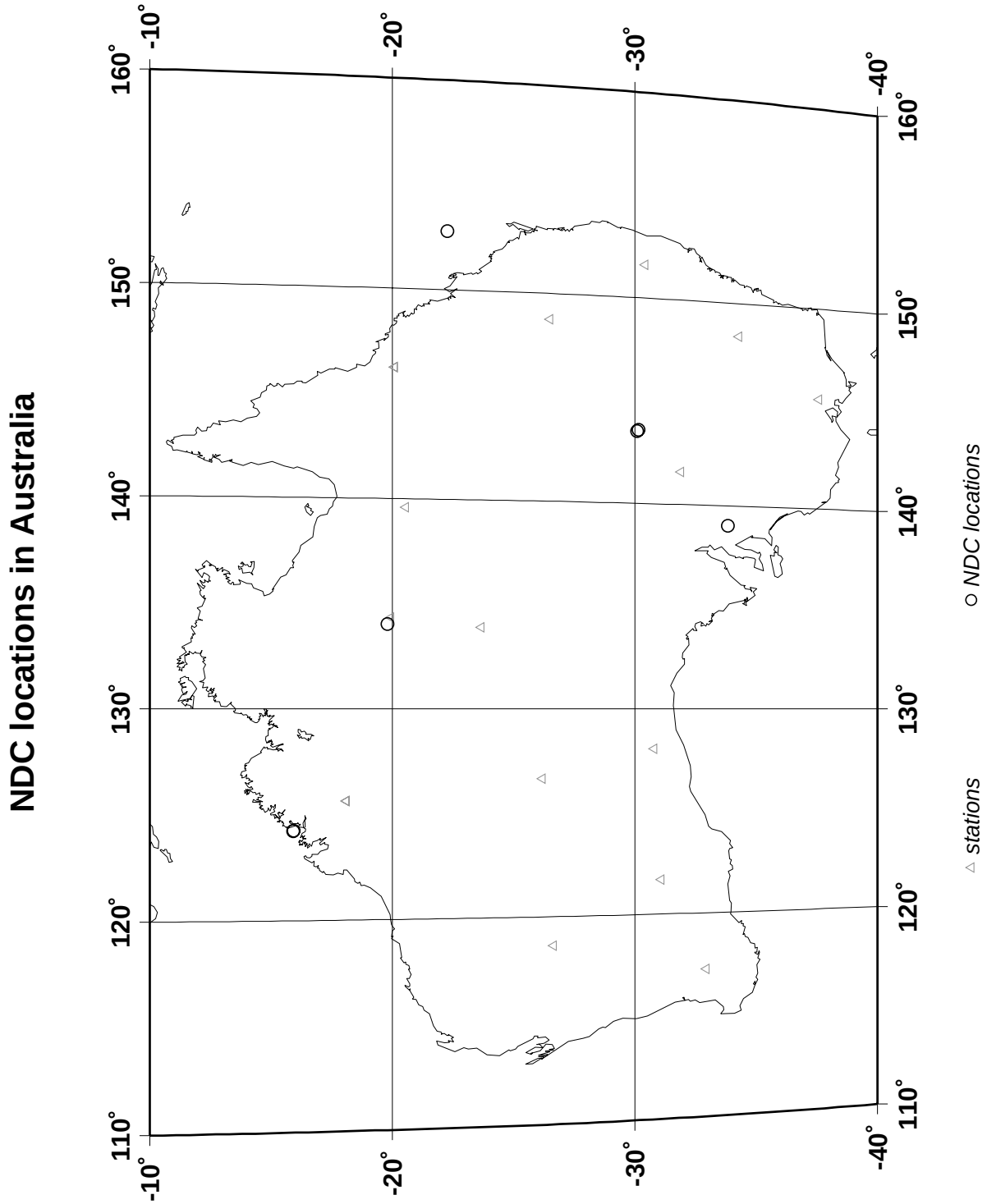

Figure 13. NDC locations for **REDB** events in Australia. Locations of stations associated with the **REDB** event locations are also shown, including the NDC stations and the GSETT-3/IMS seismic stations.